

FirstEnergy

Substation Preferred Methods  
Safe Work Practices for SF<sub>6</sub>  
Gas Insulated Equipment and  
Emissions Minimization

## **I. General**

Sulfur hexafluoride (SF<sub>6</sub>) gas is a synthetic gas used as an insulating medium in electric equipment throughout the First Energy System. The purpose of this section is to familiarize personnel with the potential hazards to health and safety while working with SF<sub>6</sub> gas-filled equipment, to detail the precautions necessary to avoid exposure to any possible unsafe conditions, and to minimize SF<sub>6</sub> gas emissions by avoiding the venting of the gas to the atmosphere.

SF<sub>6</sub> gas is a very stable chemical that has been identified as a highly potent greenhouse gas. Because of its long lifespan and potential impact on the environment, the venting of the gas to atmosphere should be avoided.

The primary use of SF<sub>6</sub> on the First Energy system is as an insulating medium in many of the circuit breakers, current transformers, and interrupting switches. Examples are the ITE G-series and Westinghouse SF and SFA circuit breakers, bushings and CT's of the General Electric type ATB circuit breakers, circuit switcher interrupters, gas insulated bus systems (GIS), and an entire group of circuit breakers referred to as "puffers".

In its normal state, SF<sub>6</sub> gas is a colorless, odorless, tasteless, non-toxic, non-corrosive, non-flammable chemically inert gas with excellent dielectric properties. SF<sub>6</sub> gas is also heavier than air and tends to collect in low places. While pure SF<sub>6</sub> gas is non-toxic, it can exclude oxygen and hence, cause suffocation. Caution and good judgment must be observed when working in confined areas, such as circuit breaker vessels. The vessel must be purged with breathable dry air and the atmosphere tested to ensure there is adequate oxygen, in accordance with confined space procedures, before employees enter.

SF<sub>6</sub> as an arc-extinguishing medium absorbs the free electrons generated by the arc, which causes the SF<sub>6</sub> to ionize. The ions recombine when they pass through the energy field to reform as SF<sub>6</sub>. Not all the ions and free atoms always recombine properly however, and some permanent breakdown products can be formed, particularly in the presence of moisture.

Westinghouse SF & SFA and ITE GA & GB circuit breakers utilize SF<sub>6</sub> gas in a two-pressure system consisting of a recirculating system, filter, oil separator, and drier. These are provided to keep the gas moisture content low, remove oil introduced by the gas compressor, and remove the arc breakdown products associated with normal breaker operations. Since the gas in these breakers is circulated through a filter system, the arc product content of the gas is minimized.

Puffer-type circuit breakers utilize SF<sub>6</sub> gas at a single pressure and ambient temperature. Bags of a special desiccant, referred to as molecular sieves, are placed in the breaker tanks to absorb water and decomposition products when the gas is agitated during operation.

When the SF<sub>6</sub> filled breakers are exposed to a severe arc for an abnormal period of time, the amount of arcing products generated may exceed the breaker's filtering system capacity, with the excess accumulating throughout the SF<sub>6</sub> system and concentrated in the interrupting heads or vessels. The arcing products may be solid or gaseous in form, with their exact composition depending on such factors as the arc duration and magnitude, moisture content, and the purity of the gas prior to arcing.

The solid arcing products are metal fluorides in a powdery form. Aluminum fluoride is white; copper fluoride is tan. Although solid arcing by-products are less toxic than gaseous by-products, the solid material is hygroscopic (moisture absorbing). If the solid by-products contact the skin immediately after encountering the atmosphere, a skin moisture reaction (hydrolysis) may form acidic chemical compounds which will cause skin irritation. After exposure to a moist atmosphere, the metal fluoride will absorb water causing the powder to become a sticky gel, which is acidic and very difficult to remove. For this reason the exposure time to atmosphere prior to clean up should be minimized.

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To avoid contact with active solid arcing products, the maintenance procedure outlined in this section should be followed. If however, accidental skin contact does occur, the affected area should immediately be washed with a mild soap and water. Eye contact should be handled as any other acid contacting the eyes (i.e., immediately rinse with large quantities of clean water and seek prompt medical attention).

In general, the gaseous arc products will exhibit a "rotten egg" odor in mild concentrations. In strong concentration, the odor will be very offensive and has the potential for serious injury.

As stated previously, SF<sub>6</sub> gas of proper purity and moisture content will not produce gaseous arc products during normal equipment operations. However, when exposed to atmosphere, breakdown may occur at temperatures as low as 300° F. For this reason, heat sources exceeding 300° F must be eliminated when handling SF<sub>6</sub> gas or the presence of SF<sub>6</sub> gas is possible. Sources include smoking, outdoor heaters, vehicle engines, welding, and any open flame.

SF<sub>6</sub> cylinder heaters, manufactured for the purpose of heating SF<sub>6</sub> gas are permissible. **DO NOT** heat cylinders beyond 125° F and **DO NOT** attempt to remove liquid SF<sub>6</sub> from any container both due to the frostbite hazard and potential damage to equipment.

Refer to the following specifications, precautions, and procedures:

## **II. Procedure Prior to Maintenance of Equipment**

- A. Due to potential environmental effects and cost of dielectric grade SF<sub>6</sub> gas, it is mandatory that SF<sub>6</sub> gas be recovered and reused whenever possible. Should gas be highly contaminated with moisture or arc by-products, the gas will be recovered and sent to a qualified vendor for reclaiming or disposal.

Scheduled major maintenance of a breaker, which has operated properly and has not exceeded the manufacturer's specifications for maximum fault current, total operations, or accumulated interrupted current, should not contain substantial quantities of SF<sub>6</sub> arc products.

1. Perform a gas moisture test. If the moisture content is within the circuit breaker manufacturer's specifications, proceed with the reclaiming. If the moisture content is greater than that allowable, perform a gas purity test. Dielectric grade SF<sub>6</sub> gas must be a minimum of 97% pure. Only gas meeting this purity may be installed in existing gas insulated equipment. If the gas is not 97% pure it may be removed with a gas reclaimer but can not be returned to the equipment until 97% pure.
2. Remove the gas using a SF<sub>6</sub> gas reclaimer. Refer to the operating manual for proper operation.  
**Caution:** Two types of SF<sub>6</sub> gas reclaimers are in general use. The older style utilizes oil type gas compressors. This type of reclaimer was developed for use with the two pressure breakers and should be used exclusively on two pressure SF<sub>6</sub> circuit breakers. The newer style reclaimers utilize oil-less compressors and are not compatible with two pressure breakers. Care must be taken not to contaminate SF<sub>6</sub> insulated equipment or oil-less gas reclaimers with oil vapor from the gas compressors utilized in two pressure breakers or old style gas reclaimers.
3. Evacuate the equipment to the manufacturer's specifications.
4. Break the vacuum with dry air until atmospheric pressure is reached.

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- B. Open the SF<sub>6</sub>-filled equipment and, WITHOUT ENTERING THE EQUIPMENT, inspect for SF<sub>6</sub> arc by-products.
- C. If no metallic arc by-product powder is visible, the Normal Maintenance Procedure outlined in Procedure III should be followed. If arc by-products are visible, follow the procedure outlined in Procedure IV, Trouble Maintenance Procedure.

### III. Normal Maintenance Procedure

- A. Purge the equipment with commercial breathing air (yellow cylinders).
- B. Measure the oxygen content within the work area. An atmosphere with a minimum of 19.5% oxygen shall be considered safe.
- C. The exposure of the molecular sieves to the atmosphere will cause moisture to be absorbed. The molecular sieve must be replaced. Any molecular sieve material replaced during normal maintenance can be disposed of as solid waste.

### IV. Trouble Maintenance Procedure

- A. If any indication of solid or gaseous SF<sub>6</sub> decomposition products are present or suspected, the following protective equipment shall be worn until the work area is determined to be clear of all decomposition products:
  - 1. Launderable or disposable coveralls.
  - 2. HEPA certified full-face respirator with acid vapor cartridges.
  - 3. Disposable gloves.
  - 4. Disposable foot covering (where necessary).
- B. Slowly purge with commercial breathing air (yellow cylinders) to exhaust gaseous products while minimizing the amount of airborne particulate. KEEP PERSONNEL CLEAR OF EXHAUST.
- C. Shut off the air and measure the oxygen content of the work area. If 19.5% oxygen is present, the work may begin.
- D. Using little or no forced ventilation to minimize airborne decomposition products, vacuum the solid products using a HEPA certified vacuum cleaner. The exhaust of the vacuum cleaner shall be vented away from the work area.
- E. All internal parts shall be wiped down with clean rags following vacuuming to remove any remaining powder.
- F. Once all SF<sub>6</sub> decomposition gasses and solids have been removed from the equipment, the solids and other contaminated materials shall be disposed of in accordance with the procedures outlined in Procedure V, Disposal of Arc Products.
- G. Maintenance work may now proceed. Remove safety equipment and clean or discard in accordance with procedures outlined in Procedure V, Disposal of Arc Products.

### V. Disposal of Arc Products

- A. All arcing products, molecular sieve material, vacuum cleaner bags and contents, cleaning rags, disposable protective equipment, and any other disposable equipment contaminated during the

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cleanup of arc products shall be considered hazardous waste and disposed of accordingly. As an alternative, the waste material may be placed in a drum with 2½ pounds of soda ash (technical grade sodium carbonate) placed on top. Water shall then be added until there is a minimum of 12 inches above the refuse material. The resulting solution will be mildly alkaline and some bubbling of CO<sub>2</sub> gas may be noted. After standing for one hour, the material may be considered neutralized. The material may now be disposed of as waste.

- B. Any non-disposable equipment, which was utilized during the cleanup of arc products, should be thoroughly rinsed with clean water, then wiped down with clean damp cloths to remove all arcing products. Place the cloths in the drum containing the other waste material.
- C. Any washable equipment, such as cotton coveralls, should be soaked in clean water for one hour, allowed to dry, and then washed in a normal manner.

#### **VI. Returning SF<sub>6</sub> gas to the Equipment**

- A. If the moisture test performed in Procdeure II A1 met the manufacturer's specification, return the gas to the equipment. Refer to the operating manual for proper operation.
- B. If the moisture test did not meet the manufacturer's specification prior to removal, retest for moisture and purity while the gas is in storage. If the gas is a minimum of 97% pure SF<sub>6</sub> and the moisture content is within specification, return the gas to the equipment.
- C. If the retested gas does not meet moisture and purity specifications, it is considered non-reclaimable in the field and must be sent to a qualified vendor for reclaiming or disposal. SF<sub>6</sub> gas reclaimers cannot remove air, oxygen, nitrogen, or freon from contaminated SF<sub>6</sub> gas.
- D. Typical SF<sub>6</sub> gas reclaimers are designed to handle SF<sub>6</sub> gas contaminates with arc by-products and moisture. However, highly contaminated gas may shorten the life of the on board filters. Refer to the reclaimer instruction book for test and maintenance procedures. Also, reclaimers utilizing oil-less compressors may be damaged by processing gas containing oil vapor.

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A functional test of a breaker capacitor trip device consists of the following:

1. With the breaker in the closed position and the auto reclosing turned off, remove the A.C. voltage supply to the breaker by opening the A.C. supply breaker to the trip circuit.
2. After a minimum of 40 seconds, attempt to trip the breaker with the control handle. (Do not use the mechanical trip lever.) If the breaker trips, the test is successful. The 40-second interval is based on capabilities of older G.E. FLO breakers. Most newer breakers have a charge retention capacity of 90 seconds or more and can be tested for the longer interval.

**CAUTION:** When working on or near the capacitor trip circuit, it is important to realize that the circuit is charged to between 380 and 560V D.C. and poses a hazard until the charge is dissipated. To dissipate that charge, turn off the A.C. supply, short the input terminals of the capacitor trip device with a 100 ohm, 100 watt resistor for 5 to 10 seconds. Verify that the charge has been dissipated by testing the circuit with a voltmeter